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Raptor's "Right Hunger" Characterization to Develop Sustainable Exclusion Areas for wildlife at Civil & Military Airports

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Abstract

The bird strike damage on aircrafts is a widely studied matter [1] with a high economic impact on stakeholders finances. Some authors estimate it in about USD1.2 Billion for nowadays commercial worldwide activity [2], and more than USD937 million in direct and other monetary losses per year just for the United States, as an example of civil aviation industry [3]. The present techniques to face this problem have been previously analyzed in order to decrease the wild life hazards at the airport facilities [4] however nowadays there is a new point of view to prevent this risk at airports that requires an interesting approach in relationship with industrial process improvement examples, such approach lies on preserving the natural life at the airport facilities by developing raptor micro-habitats than change into exclusion areas when the risk of being hunted is recognized by the existing wildlife.
Therefore, the main goal of this paper is to share several experiences developed at the Spanish dual airport (military & civilian) of San Javier (Spain), as a case of study in where the mathematics and nonlinear sciences provides the foundations of the ontological knowledge for falconry performance as a Wildlife Control Technique for airport facilities.

Keywords: Airport Falconry, Right Hunger, Sustainable Exclusion Areas
AMS 2010 codes: 49J10, 62P10, 92B05.

1 Falconry and others Wildlife Control Techniques.

The study of factors that may affect the wildlife presence at airport areas requires a multidisciplinary and complex knowledge which is build up analyzing first the wildlife and its diversity, the main features of the

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species, the habitat, the migratory routes and finally studying the airport facilities and its working procedures [5] which may last a long research in time.

This complex dimension makes that any experience achieved before is most often of not utility in a general study, because it is not easy to apply experiences from one case of study to others. However most of the research papers still analyzing these complex characteristics case by case, reporting new solutions that were developed at the same time that the need was detected. As an example, Spain is one of the countries that started in the 70's to manage wildlife hazards by using raptors at airports in order to generate exclusion areas. Since then, other countries followed alternative solutions that nowadays, in addition to the use of raptors, give rise to the so-called Wildlife Control Techniques [4, 6].

All the references analyzed showed that the authors agree that the most effective of these techniques still being the use of Raptors or Falconry beside other WCT, even some of them redefine falconry in order to preserve the wildlife as a main purpose, which affect the technique to make focus not on hunting but on dissuading other species of being close to hot airport transit areas [7].

The falconry once more, is an example of a technique that acts before the risk is generated because it creates exclusion areas which means areas in where the wildlife is not expect to be present as a consequence of the risk of being captured by the raptor. However this process is a tough labour for the falconer which requires a singular training on each raptor in order to lead the raptor's instinct to behave in a specific way to success in creating this exclusion areas, hence this becomes the falconer Knowledge.

The knowledge Management study of falconry, applied to Airport Wildlife Control Services, forces any stakeholder to analyze the standards of how the Intellectual and Relational Capital works together to manage the facilities or infrastructures beside this activity in order to successfully prevent the bird-strike hazard (see fig. 1). Such matter has come up to the point in where just the falconer know-how must be considered of high value to compete when an airport public contest takes place, and therefore this is the reason of why there are not enough references on this matter.

The aim of this research is to apply mathematics and nonlinear sciences to analyze this knowledge in order to define and share further standards for airport falconry through a case of study analysis.

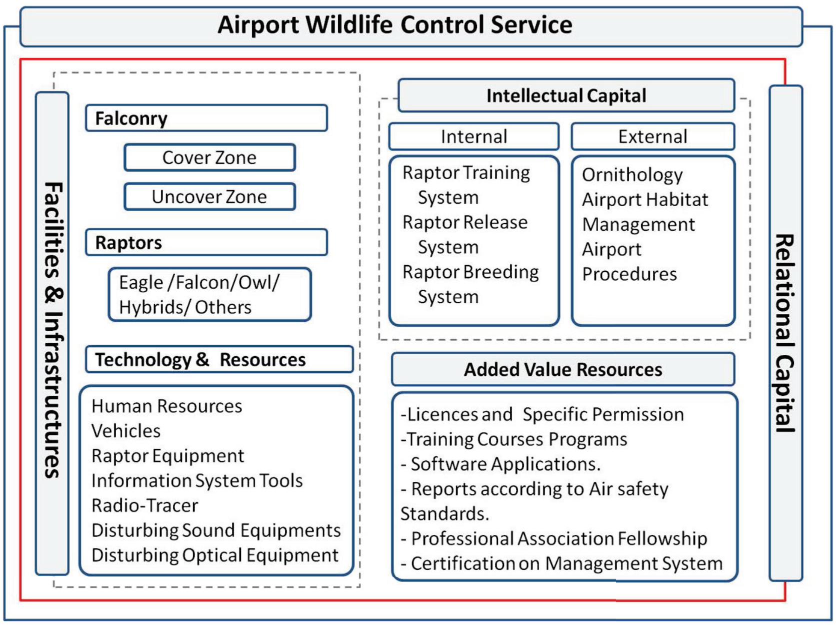

Fig. 1 knowledge Management study of Airport falconry (Own).

2 Right Hunger and Raptor's Behaviour.

According to most of references in concern with falconers Know-How, the breeding process is the complex-key to understand the raptor status which may determine the falconer decision process, this key is characterized by several factors that have influence on how effective the falconry techniques are when they are arranged to create exclusion areas in order to prevent bird strikes. However, over all of them, the most relevant factor in direct relationship with the raptors behaviour and their availability to face any prey, is called "Right Hunger" (RH) which represents the most desired grade of hunger for any raptor that ensures their haunting feeling over the existing wildlife and what will finally fright any prey and as an answer will keep away the wildlife from the raptors hunting ground.

Unexpectedly once more as there are not enough references on this matter, the control process over the right hunger still being nowadays set up by the falconer experience on each raptor, what means that the falconer has to find out day by day the exact amount of food that the raptors needs in order to flight properly.

However even today when some falconers believe that they have widely analyzed their own raptor right-hunger, it happens sometimes that there are not any reasonable explanation for bad results when the raptor were perfectly feed. This still being a problem since it was detected long time ago, when at seventeen century the Treatise of Hawkes and Hawking of Edmund Bert was wrote circa 1619, which summarized the problem as follow:

"I have flown a Hawke all one season, and never fed but upon the best meat I could, she never tasted Beefe, neither was her feathered meate (but very very feldome) cold; and to helpe her metter, a night did hardly efcape me but I thrust out the marrow of the wings of either Ducke, Pheasant, Partridge, Dove, Rooke or such like."

Back on the right hunger original definition, it states that if the raptor is fed in excess, he will not fell the need of flying when is ordered so and likewise in contrast, will be too weak to flight when he has been poorly fed. The breeding problem statement is focused then, in relationship with the nutritional need of raptors, in developing a case by case strategy in order to complete the falconers knowledge by a continuous monitoring on each specimen, recording its weight variation and the daily amount of food provided.

Back on the references search as a starting point, some authors defined a threshold value for the minimum amount of calories that any raptor may need just to survive or what it is called, the Basal Metabolic Rate (BMR) or Minimum Energy Cost (MEC). This rate tries to simplify the energy balance thanks to allometric equations [8] which provides an estimation of calories per day that any raptor, in rest and in a thermally neutral environment, may need to achieve his need in terms of nutritional components.

This equation (1) explains the relationship that exist between the raptor weight and the basal metabolic need, meanwhile other factors like sex and age among others may be dismissed from the equation, due to a direct relationship within the weight factor.

$$\mathrm{BMR} = \mathrm{MEC} = 78(\mathrm{RW})^{0.75}. \tag{1}$$

"Nevertheless BMR equation just provides information about the minimum amount of calories that any raptor needs to survive in a rest and neutral environment, but what happen when the environment or the activity changes? In order to answer this question some authors developed an interesting study that defined the daily energy requirements or Specific Metabolic Rate (SMR) which is calculated by multiplying a factor and the BMR.

Once that the BMR is characterized as an nonlinear process the problem statement can be formulated in terms of forecasting for the factor that brings together the expected right hunger (RH) and the specific metabolic rate (SMR) but focusing on the Airport Activity as a case of study in order to improve falconry to decrease the Bird Strikes risk at these facilities.

Table 1 Activity Factors [9]

Activity	Correction Factor
Animal at rest	1.3-1.5xBMR
Animal with injury	1.5-2.5xBMR
After Surgery	1.5-2.5xBMR
Actively Exercising	2.6xBMR (Depends on amount of exercise)
Growing Young	2.5xBMR (Depends on rate of growth)

Table 2 The falconer evaluation range

Value	Description
D/V	The Falconer did not release the raptor due to rest season or high range wind.
1	The falcon flies away and did not return when called.
2	Bad flight, the falcon alights unexpectedly.
3	Regular flight. The falcon will neither fly at the desired high or around the whole zone.
4	Good flight. The falcon flies at proper high but will not cover the whole area assigned.
5	Very Good flight. The falcon flies over the whole area assigned but returns lately
6	Excellent flight. The falcon flies at,desired high even success in hunting and returns when is called.

3 The case of study.

In order to analyze how the RH could modify the raptor BMR, this research selected a dual use airport (civil & military) where the falconry is being used since the year 2002 by the enterprise Jesús Brizuela Ltd that was founded by a recognized expert on this field who was a coworker of Félix Rodríguez de la Fuente (father of the Airport Falconry at Spain in the 70's).

The falconry technique applied at San Javier Airport since 2004 up to 2010 followed the traditional guidelines or standards of falconry, where the falconer takes care of the raptors, plans diary releases, designs the nutritional daily schedule and takes under control the weight to keep the raptors as much close to what the falconer believe is the right hunger for each one and as a result of all this process then updates the handbook in where all this information is recorded. Since 2010 a new qualitative variable was add to the database, in order to provide a professional feedback about the breeding process therefore the falconer could evaluate the raptor release in a range from 1 to 6 (see table 2).

The working database was finally defined with seven variables per day and raptor which were: A=Age (days), W= Weight (gr), F= Food assigned (calories), T=Temperature (Celsius), RH= Relative Humidity, $Patm$= Atmospheric Pressure (atm) and finally V= Falconer fly evaluation (1-6). The final database containeds 2.550 data per raptor and year, 25.550 data per falconry (10 raptors per falconry) and for the total period of ten years analyzed (2004-2014) 255.000 records. As a result it took for a half time researcher about six months just to digitalized the falconer's hand notes line by line.

3.1 The nutritional question.

As the research went over, some initial considerations had to be assumed in order to quantify nutrition through the total amount of food provided to each raptor. In first place and after reviewing the most relevant references in relationship with nutritional balance (see fig. 2), it showed how complex is to find out the exact digestive efficiency on real time for each raptor [10], the exact percentage of vitamins and proteins contained at the raptor's food as well as the rest of factor that are the foundations of any food requirement.

The answer to this first problem was found in the captivity nature of airport falconry, where the food is

Table 3 Nutritional components for each 0.8g of One-day chicken (40g) [11]

Nutritient	%	Nut.	%	Nut.	%
P	42.503	Cu	0.010	Vit-A	0.014
Na	15.623	Co	0.002	Vit-B1	0.005
Mg	2.063	Ca	39.176	Mn	0.000
Fe	0.479	Vit-E	0.131		

Table 4 Food Calories Conversion Table

Food Description	Kcal/unit
1 Day/Chick	39.6
Chicken Wing	57.96
Chicken Breast Portion	38.22

typified and provided by a commercial food service that guarantee the best quality and the nutritional information according to the laboratories analysis and test delivered to trace it [11]. As a matter of fact, the nutrient, proteins and vitamins percentage are of no use for the RH definition, due they are supplied in the same proportion when the raptor is fed and therefore can be calculated at any time just knowing the food units supplied at each time (see table 3). Finally the database include a column with the feeding information but transformed into Calories tanks to a direct conversion of food units to calories according to table 4, extracted from the falconry food provider.

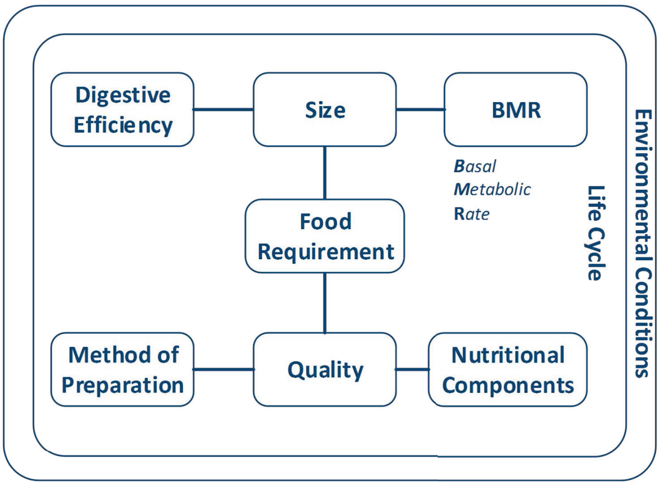

Fig. 2 Food Requirement Factors [10]

3.2 Preliminary Results.

The plot of calories provided (actual SMC) vs. Basal Metabolic Rate (BMR) (see fig. 3) showed how sometimes the falconers lead the raptors to a critic right hunger status, perhaps trying to slim down the raptor to improve the out coming results by increasing the raptor hunting feature, other times the falconer provides more calories than needed, probably in order to fat the raptor or to ensure their health.

The control process involved was inefficient at the beginning due to a lack of information for the variables adjustment because the falconer feedback was limited to a few records on falconer mind, this circumstance increased the variability because the falconer did not have a clear view about the actual state of each raptor at any time.

The plot of the Feeding Factor (FF) which is the quotient between SMC and BMR besides the locally-

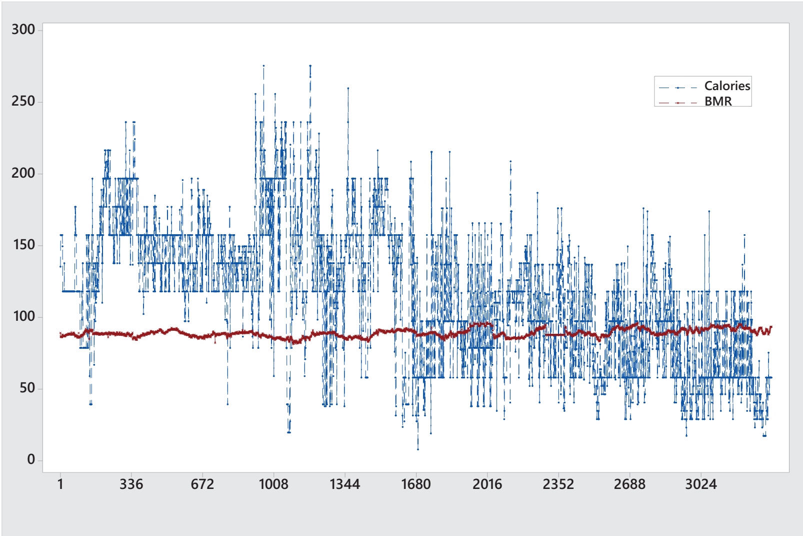

Fig. 3 2004-2014 SMR vs. BMR example plot

weighted scatterplot smoother ($f = 0,25$) showed how the falconer corrected the feeding trend (see fig. 4) after writing down the evaluation rage and analyzing the last records, so the process was improved since an early beginning by decreasing the amount of food. Nevertheless, this trend does not represent a valid correction factor for the activity factors of table 1 because it does not consider the season factor as a variation input.

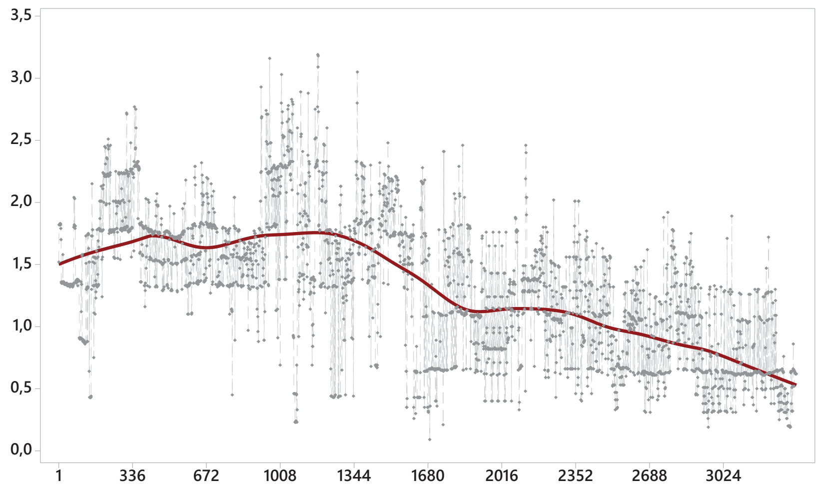

Fig. 4 Factor lowess plot $f = 0,25$.

The SMC/BMC ratio gives as an answer a value higher than 1 when fattening and lower than 1 when sliming, so the first step to analyze the time series was to find out, for all the records, which was the falconer purpose and which was the result. For this purpose, an I&T Tool was designed and offered to the falconer in order to easily provide him of a minimum statistical information as a relevant feedback (see fig. 5).

Figure 5 represents the minimum statistical information for a Falco Rusticolus x Cherrug specimen as an example provide by the IT tool, what could help the falconer to find out the expected value of the Righ Hunger defined as the factor that modify the BMR value in order to guarantee a certain expected result (from 1 to 6 according to evaluation table).

The results were the feedback that the falconer needed to compare if his knowledge about each raptor was or was not correct because most of the times the falconer usually believed strongly wrong that too much food could affect negatively the raptor release when the raptor just needed more food to avoid being too weak to fright any prey. In relationship with the season, the results (see figs. 6 & 7) showed that raptors needed less calories at winter than summer which is explained thanks to a positive impact of the number of flight operations at SJV Airport during tourism season, which requires more raptor releases in order to keep the wildlife out of the hot areas at the airport.

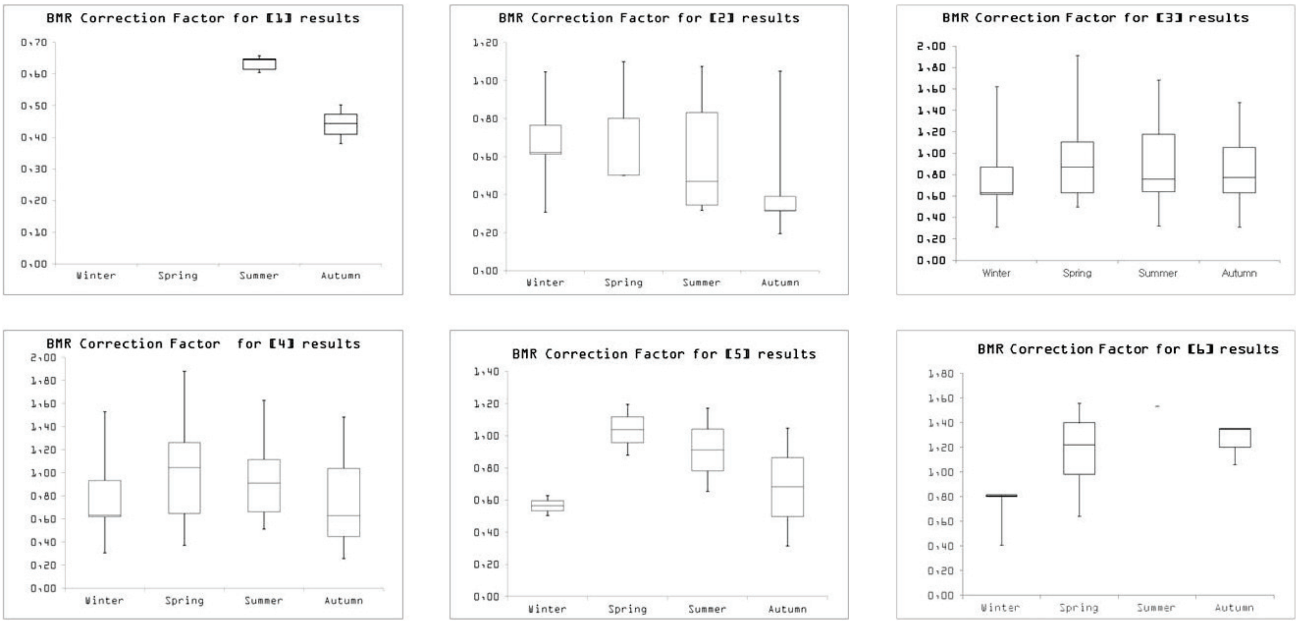

Fig. 5 Box and Whisker plot for Falco Rusticolus x Cherrug.

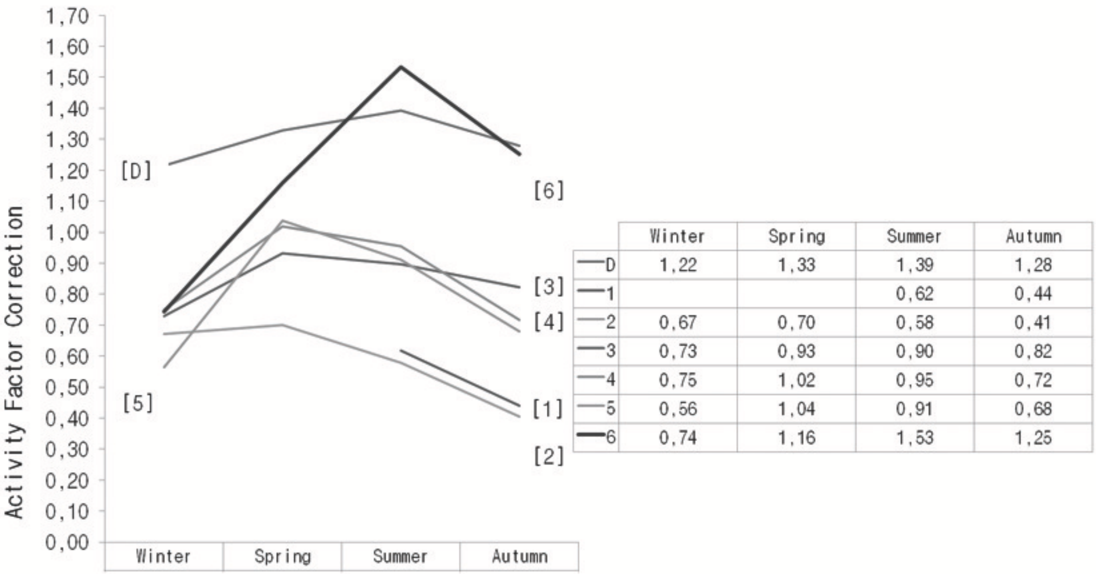

Fig. 6 Example of SMR/BMR Medianan results from Falconges Software.

Some other results shows unexpected correlation between the feeding factor (SMC/BMC) and the results (see fig. 6), like it happens in winter season (autumn as well) when suddenly a lower value of the factor gave as an answer an evaluation of 5, out of a maximum of 6, when it should lead to a worse results. The research brings tow possible answer to these results, the first one is linked to meteorological conditions beside low raptor number of releases at the airport off season, because the airport allocation of this case of study belongs to a light winter/autumn definition whenever it is very common to find out a wide range of days with excellent weather conditions among others which are more related to the season itself.

The lowest number or raptor releases also affects, providing a median which does not represent the most common value for most of the raptors, therefore in order to provide effective support to the falconer decision process it show up to be of more interest to plot the process control limits defined by the first and third quartile beside the median (see fig. 7). The control limits were defined so by an exponential regression which offered the highest value for the coefficient of determination R^2 at each case for each season (see eqs. from table 5), the graphical information provides a valid range for the falconer trend analysis and prediction for the raptor's behaviour during each season while the regression formulas are of use to provide a numerical estimation provide by Falconges software application.

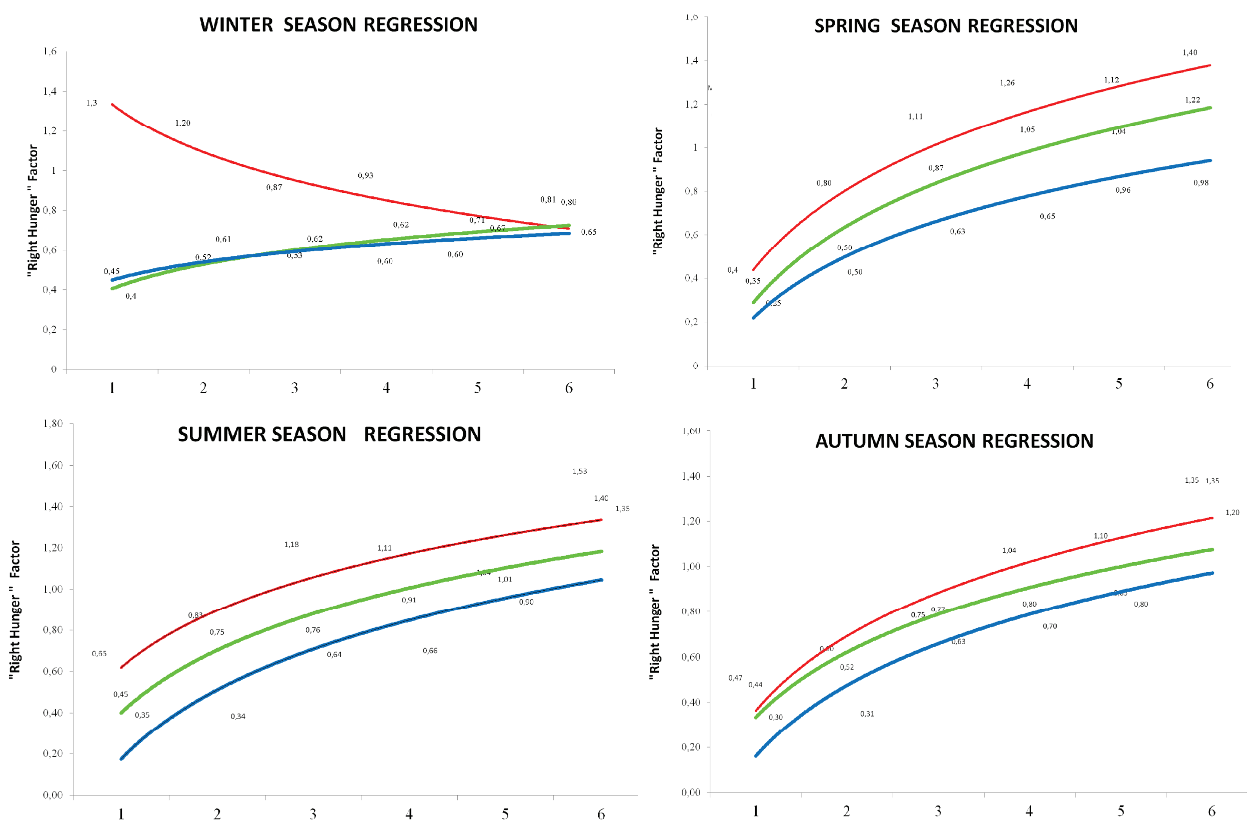

Fig. 7 Season Control Limits for the Raptor Feeding Factor and The Expected Flight Evaluation.

4 Conclusions

The main conclusion of this research is focused on disclaiming, for the Airport Falconry purpose, the feeding factor of table 1 and accepting instead the range of values calculated throught equations at table 5, in order

Table 5 Seasonal expected Q3, Median and Q1 of raptor flight results depending on the Feeding Factor(FF)

Season	$E(V_{Q3})$	R^2	$E(V_{Med})$	R^2	$E(V_{Q1})$	R^2
Winter	$\exp\left[\frac{1.335-FF}{0.349}\right]$	0.83	$\exp\left[\frac{FF-0.4058}{0.1786}\right]$	0.81	$\exp\left[\frac{FF-0.4496}{0.1319}\right]$	0.79
Spring	$\exp\left[\frac{FF-0.4391}{0.5242}\right]$	0.93	$\exp\left[\frac{FF-0.289}{0.05}\right]$	0.947	$\exp\left[\frac{FF-0.2195}{0.4029}\right]$	0.925
Summer	$\exp\left[\frac{FF-0.6188}{0.4}\right]$	0.81	$\exp\left[\frac{FF-0.4}{0.437}\right]$	0.83	$\exp\left[\frac{FF-0.1733}{0.4873}\right]$	0.73
Autumn	$\exp\left[\frac{FF-0.3636}{0.475}\right]$	0.896	$\exp\left[\frac{FF-0.3348}{0.414}\right]$	0.78	$\exp\left[\frac{FF-0.1615}{0.4529}\right]$	0.81

to follow a model which results provides the best adjustament to the expected value for each seasonal need. Nevertheless this research also suggests new questions about Airport falconry as it is the estimation of correlation for meteorological conditions, right hunger and flight evaluation, further studies also may make focus on new allocations as new cases of study for which the software developed may be a valid tool to analyze quickly new environment and therefore to set new mathematical models which may improve the Airport falconry techniques to its higher level. Up to this point the meteorological information has been provided thanks to the Spanish Meteorological Agency (AMET) for the study period (2004 to 2014) which worth a contribution recognition of 1.500EUR and has been already entered in a new database in order to proceed with this research in a short amount of time.

The search of ontological knowledge in relationship with airport falconry, should also answer to a question that was not answered yet with the allometric BMR, as in falconry it is common practice to handle mixed-race raptors, the final question could be: does the hybrid raptors and non hybrids have the same equations to find out the right hunger? is the gender a relevant factor? In advance to this future research the process will follow a non parametric test, Kruskal-Wallis to study all the raptors at the same time in case they do not follow a normal distribution, and a Mann-Whitney test in where all the raptors will be grouped in two, in order to identify any similarity in bi-dimensional classifications.

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